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(19)

(54) MONITORING THE FLOW OF FLUIDS

(71) We, SIEMENS AKTIENGESELLSCHAFT, a German company, of Berlin and Munich, Germany, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to the monitoring of the flow of fluids.

There is described in Patent Specification No. 1,239,622, an apparatus that can be used, for instance, to monitor the flow of a coolant in a power generation plant. This apparatus comprises a probe around which in use is arranged to flow a stream of coolant whose flow is to be monitored. The probe itself is provided with a sensor member, in the form of an electrical component having a temperature-dependent electrical parameter, and with heating means for supplying heat to that sensor member. The sensor member of such a probe can be so heated by such heating means that the rate at which heat is extracted from the sensor member by virtue of heat transfer from the probe to the coolant stream will be greater than a predetermined value when the flow conditions of the stream lie within preselected admissible limits, but that heat will be extracted at a rate less than the predetermined value if the flow conditions of the stream lie outside the preselected admissible limits, thereby causing the temperature of the sensor member to rise. Since a rise in the temperature of the sensor member will be accompanied by a corresponding change in the temperature-dependant electrical parameter, the magnitude of this parameter, when detected by a suitable metering circuit, then provides a measure of the flow conditions of the stream. The sensor member may comprise a temperature dependent electrical resistor, in which case the electrical parameter is simply its ohmic resistance, or a thermocouple junction of a thermocouple, in which case the electrical parameter is the thermoelectric electromotive force operatively generated by the thermocouple.

It is described in the Patent Specification No. 1,239,622 how selection of the resistance characteristic of a heating resistor constituting the heating means and connection of that resistor can be made such that the change in resistance of the heating resistor acts to increase the measure of the change in the electrical parameter observed by the metering circuit. The heating resistor can be included in the metering circuit and have its temperature-resistance characteristic suitably adapted to that circuit. Thus, for example, a heating resistor can be employed that has a positive temperature coefficient, that is to say, one whose resistance value is higher in the hot state than in the cold state. Then, when cooling is reduced, or when the probe is extracted from a stream of coolant, a particularly large increase in the temperature of the sensor member is brought about since not only is less heat dissipated from the probe, but more heat is produced in the probe because the resistance of the heating resistor, and thus its heating power, is higher as its temperature is higher.

It may be advantageous to include a heating resistor having an opposite temperature-resistance characteristic in the metering circuit. By this means, the temperature behaviour of the heating resistor can be utilised to increase the measuring range. If, for example, a nickel-iron alloy or another material having a negative temperature coefficient is chosen as the material for the heating resistor, the resistance of the heating resistor, and thus its heating power, is reduced when, as a result of the probe ceasing to be immersed in a stream of coolant, the heating of the probe increases.

Since the values of heat transfer to air

[*Price 25p*]

and water are in a ratio of substantially 1 to 6, while the dissipation of heat in flowing water varies camparatively little, a large part of the available temperature gradient would be used up for monitoring a change in the fluid surrounding the probe from static air to static water and only a small interval would remain for monitoring variation in liquid flow in that region of the flow which is of interest. If a material having an appreciable negative temperature coefficient is chosen for the heating resistor, a change in the resistance of the resistor of at least 30% occurs if there is a temperature difference of about 120°C. between the temperature of the sensor member when the probe is in air and when it is in a coolant such as water. Since the heating resistor is maintained at a substantially constant voltage, the heating performance of the probe is about 30% higher in the coolant than in air. Use of such an arrangement therefore constitutes a simple means of appreciably widening the measuring range of the immersed probe.

Regardless of the curve followed by the temperature-dependent resistance value of the heating resistor, i.e. regardless of whether it has a positive or negative temperature coefficient, considerable heating of the sensor member will always occur when the probe ceases to be immersed in the flow of coolant. It is desirable, therefore, to limit heating of the probe without detrimentally affecting the measuring sensitivity and the width of the measuring range.

According to the present invention there is provided a flow-monitoring probe including a sensor member which has a temperature-dependent electrical parameter, and heating means for influencing temperature at the sensor member and causing heat to be exchanged between a sensing surface of the probe and a stream of fluid flowing in contact with that surface when the probe is in use, the heating means being arranged with the sensor member in a probe body which defines the said sensing surface, the sensor member being connectible to means for detecting a change in the said electrical parameter, occurring in use of the probe as a result of a change in the rate of such heat exchange, thereby to detect a change in the fluid flow conditions at the said sensing surface, and the probe further including automatic adjustment means connected with the heating means for varying the energisation thereof so as to bring about a change in the rate of such heat exchange when the temperature at the said sensing surface reaches a preselected limiting value.

The automatic adjustment means may act to reduce the energisation of the heating means abruptly when the temperature at the sensing surface rises to the preselected limiting value or, alternatively, may act to reduce the energisation continuously as the temperature at the sensing surface rises above the preselected limiting value.

The preselected limiting value can be chosen such that the change in the rate of heat exchange commences below the upper limit of the measuring range, but it may alternatively be chosen such that this change occurs above the upper limit.

The heating means of a probe embodying the invention may be operative to supply heat to the sensor member such that when the probe is in use heat is extracted from the sensor member at a rate greater than a predetermined value when the fluid flow conditions of a fluid whose flow is to be monitored lie within preselected admissible limits, but is extracted at a rate less than the said predetermined value when the fluid flow conditions lie outside the said preselected admissible limits, detection by such detecting means of the magnitude of the said electrical parameter, being dependent upon the fluid flow conditions of the said stream, serving to provide an indication of whether or not the fluid flow conditions lie within the said preselected admissible limits.

The automatic adjustment means can comprise a resistive component having a temperature-dependent resistance value, which is connected to actuate switching mean for controlling the electrical power supplied to heating means in the form of a heating resistor. For this purpose, there may be employed as the resistive component a semiconductor resistor having a positive temperature coefficient. Such a semiconductor resistor can be disposed in the immediate neighbourhood of the sensor member within the probe, in which case it is embedded, together with the sensor member, in an electrically insulating, but thermally highly conductive embedding mass. A particularly suitable embedding mass is a cured resin containing powdered aluminium. The individual aluminium particles produce a good thermal conductivity, but they are separated from one another by the resin mass, so that no continuous current bridge is formed and a good electric insulation is effected.

Such a resistive component having a positive temperature coefficient may be directly connected in the circuit of a relay whose contacts effect a change-over of the electrical power supply for the heating resistor. The said resistive component has, for example, a rated temperature of 150°C. and at this temperature directly operates a relay which reduces the heating voltage to a value which prevents over-heating of the sensor member when the probe is no longer immersed.

The automatic adjustment means may equally be arranged to bring about an increase in the energisation of the heating means when the temperature at the sensing

surface falls below a preselected limiting value lying, for instance, in the region of the lower limit of the measuring range, i.e. at the region where the temperature values of the probe are low. In addition, it is also possible to effect a corresponding stepwise changeover with one or more resistive components having a positive temperature coefficient, in which case the energisation of the heating means is increased in the region of low temperatures (in the region of the lower limit of the measuring range), is then changed to a medium value in the actual measuring range, and is finally changed to a lower value in the region of the upper limit of the measuring range.

For a better understanding of the invention, and to show how the same may be carried into effect, reference will now be made, by way of example, to the accompanying drawing, in which:

Figure 1 is a diagrammatic sectional view of part of a flow-monitoring probe embodying the present invention, and

Figure 2 is a circuit diagram of that device.

The illustrated probe comprises a probe body 1, on to an end face 2 of which a stream of fluid, for instance, liquid coolant, is operatively arranged to flow laterally in the direction indicated by the arrow 3. Heating means are provided in the form of a spiral resistive heating winding 4 which has a supply conductor 4a and lies as a sheathed conductor flat on a trough-form base portion 5 in the end face 2 of the probe. The good heat-exchange properties obtained with this arrangement can be further improved, if desired, by use of an embedding mass 6 which has good thermal conductivity and contributes to a reduction of the time delay constant for the detection of changes in the flow conditions of the fluid stream. Trough edges 7 are made so high in relation to the trough base portion 5 that, when the rate of flow is slowed down and the fluid thus begins to stagnate in the trough, a film of vapour soon forms at the heat exchange surface, i.e. the end face 2, whereby the heat exchange between the fluid and the device is suddenly greatly impaired. The incipient film evaporation gradually increases automatically by virtue of the fact that the trough base portion 5 rapidly reaches a higher temperature and so a vapour film soon spreads over the whole of the trough base portion 5.

Conversely, with a higher rate of flow, the trough edges 7 produce a whirling of the fluid so that fresh fluid continuously reaches the trough base portion 5 and extracts an ample amount of heat therefrom. Of course, further flow-hindering elements may be provided in addition to the trough edges 7.

In addition, it is advantageous to provide instead of a single trough-form base portion a plurality of such trough-form base portions and, if desired, create a honeycomb-like or other roughened structure in order to provide a larger number of recesses in which no appreciable dissipation of heat occurs with slow or static fluid flow.

In the illustrated probe, there is employed as a sensor member 8 a temperature-dependent resistor, preferably a semiconductor resistor, for example a thermistor, which lies flat on the trough base portion 5 in order to provide for good heat exchange. There is here employed as the embedding mass 6 a cured synthetic resin containing powdered aluminium, which both has good electric insulation and is endowed with high thermal conductivity, so that the time delay factor in the measurement of flow conditions is small. In addition to the thermistor 8 with the supply conductors 8a and 8d, there is here provided as a resistive component of automatic adjustment means for varying the energisation of the heating means, i.e. the winding 4, a resistor 9 which has a positive temperature coefficient and is connected between supply conductors 9a and 9b. The resistor 9 acts to operate a relay when the temperature reaches a particular value, this relay reducing the heating voltage for the heating winding 4 to a value such as to prevent overheating of the sensor member when the probe is not immersed.

The circuit shown in Figure 2 is fed from an alternating-current supply system through a transformer 10, of which the secondary winding directly supplies the resistive heating winding 4 with alternating current, while there serves for the sensor member 8 a unidirectional voltage rectified by rectifiers 11, 12, 13 and 14. Connected with the supply conductor 9b leading to the resistor 9 having a positive temperature coefficient is a relay 15 whose switching contact 16 changes over the heating voltage. At a rated temperature of, for example, 150°C., the relay 15 is directly controlled by the resistor 9 having a positive temperature coefficient such that the switching contact 16 changes over the supply conductor 4a for the heating winding 4 from a higher voltage tap 17 to a lower voltage tap 18. In this manner the heating voltage is reduced to a value such as to prevent overheating of the probe when it is not immersed. The circuit of the sensor member 8 includes a resistor 20 associated with a measuring device 19, from which resistor 20 measuring signals are transmitted to the measuring device 19.

It will be appreciated that an embodiment of the invention can be used to monitor the flow of a stream of liquid coolant in a cooling circuit of a power generation plant.

Attention is drawn to the Applicants' patent specification No. (Serial No. 1312829)

(31465/70), which also relates to the monitoring of the flow of liquid coolants and describes a flow-monitoring probe similar to that described with reference to Figure 1 of the drawing accompanying the present specification.

WHAT WE CLAIM IS:—

1. A flow-monitoring probe including a sensor member which has a temperature-dependent electrical parameter, and heating means for influencing tempertature at the sensor member and causing heat to be exchanged between a sensing surface of the probe and a stream of fluid flowing in contact with that surface when the probe is in use, the heating means being arranged with the sensor member in a probe body which defines the said sensing surface, the sensor member being connectible to means for detecting a change in the said electrical parameter, ocurring in use of the probe as a result of a change in the rate of such heat exchange, thereby to detect a change in the fluid flow conditions at the said sensing surface, and the probe further including automatic adjustment means conected with the heating means for varying the energisation thereof so as to bring about a change in the rate of such heat exchange when the temperature at the said sensing surface reaches a preselected limiting value.

2. A probe as claimed in claim 1, wherein the automatic adjustment means act to reduce abruptly the energisation of the heating means when the temperature at the said sensing surface rises to the said preselected limiting value.

3. A probe as claimed in claim 1, wherein the automatic adjustment means act to reduce the energisation of the heating means continuously as the temperature at the said sensing surface rises above the said preselected limiting value.

4. A probe as claimed in any preceding claim, wherein the said sensor member comprises a temperature dependent electrical resistor whose ohmic resistance constitutes the said electrical parameter.

5. A probe as claimed in any one of claims 1 to 3, wherein the said sensor member comprises a thermocouple junction of a thermocouple, the thermoelectric electromotive force operatively generated by the thermocouple constituting the said electrical parameter.

6. A probe as claimed in any preceding claim, wherein the heating means are operative to supply heat to the sensor member such that when the probe is in use heat is extracted from the sensor member at a rate greater than a predetermined value when the fluid flow conditions of a fluid whose flow is to be monitored lie within preselected admissible limits, but is extracted at a rate less than the said predetermined value when the fluid flow conditions lie outside the said preselected admissible limits, detection by such detecting means of the magnitude of the said electrical parameter, being dependent upon the fluid flow conditions of the said stream, serving to provide an indication of whether or not the fluid flow conditions lie within the said preselected admissible limits.

7. A probe as claimed in any preceding claim, wherein the heating means comprise an electrical heating element for connection to an electrical power supply.

8. A probe as claimed in claim 7, wherein the automatic adjustment means comprise temperature-sensitive electrical resistive means which are disposed in thermal contact with the said sensing surface and are connected with control means whose actuation, in response to variation in resistance of the electrical resistive means when the temperature at the said sensing surface reaches the said preselected limiting value, effects the said change in the rate of such heat exchange.

9. A probe as claimed in claim 8, wherein the said control means comprise switching means for controlling the electrical power supply to the said electrical heating element, the said actuation effecting a reduction in the electrical power supplied to the electrical heating element when the probe is in use.

10. A probe as claimed in claim 8, wherein the said control means comprise a relay whose actuation in response to the said variation in resistance of the electrical resistive means effects a change in the electrical power supplied to the electrical heating element.

11. A probe as claimed in claim 8, 9 or 10, wherein the temperature-sensitive electrical resistive means comprise a semiconductor resistor having a positive temperature coefficient.

12. A probe as claimed in anyone of claims 8 to 11, wherein the electrical resistive means are disposed within an electrically insulating but thermally highly conductive embedding mass.

13. A probe as claimed in claim 12, wherein the embedding mass is a cured resin containing powdered aluminium.

14. A probe as claimed in any preceding claim, wherein the automatic adjustment means are operative to increase the energisation of the heating means when, in use of the probe, the temperature at the sensing surface falls below a preselected limiting value which is less than the said preselected limiting value of claim 1.

15. A flow-monitoring probe substantially as hereinbefore described with reference to Figures 1 and 2 of the accompanying drawing.

16. A method of monitoring the flow of a stream of fluid by means of a flow-monitoring probe as claimed in any preceding claim.

17. A power generation plant, including a cooling circuit through which is arranged to flow a stream of coolant fluid, and a flow-monitoring probe, for monitoring the flow thereof, as claimed in any one of claims 1 to 15.

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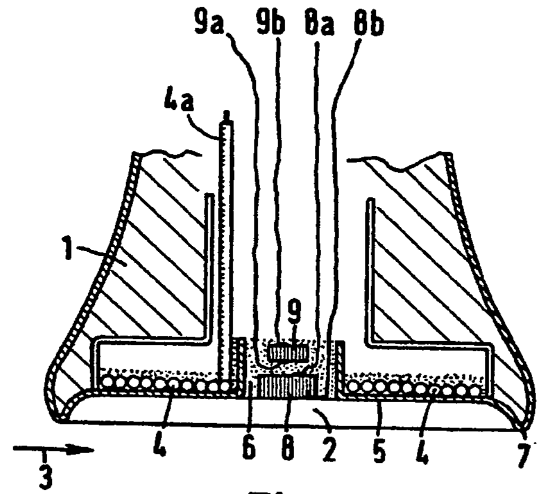
9a
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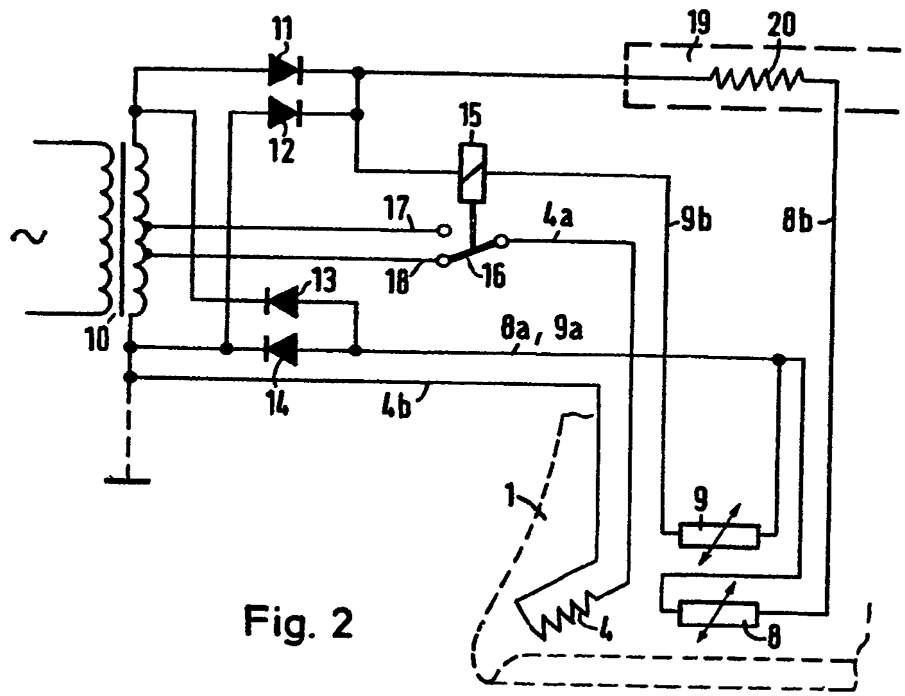
Fig. 1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8a, 9a
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Fig. 2